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Assistive Technology and Universal Design for Learning: Two Sides of the Same Coin

David H. Rose, Ted S. Hasselbring, Skip Stahl, and Joy Zabala

Over the past decade, evolving technologies have revolutionized the way we do business, communicate, make war, farm, and provide medical treatment. New technologies are also transforming education, and in no domain more dramatically or successfully than in the education of students with disabilities.

Although the existing benefits of technology for students with disabilities are already widely recognized (e.g., Edyburn, 2003; Hasselbring & Glaser, 2000; Raskind & Higgins 1995; Rose & Meyer, 2002), the potential benefits are likely to be even more profound and pervasive than present practices would suggest. To ensure full realization of technology's potential for students with disabilities, the Office of Special Education Programs (OSEP) has funded two national centers that have a strong focus on technology: the National Assistive Technology Research Institute (NATRI) at the University of Kentucky and The National Center on Accessing the General Curriculum (NCAC) at CAST.

While both centers focus on the role of technology, their work is neither duplicative nor competitive. Rather, each is researching a distinct role for technology in improving education for students with disabilities, assistive technology (AT) and Universal Design for Learning (UDL), respectively. The question of how these two approaches can enhance and even support one another for the further benefit of students with disabilities is fundamentally important. We have engaged in early discussion of this issue with the National Center for Technology Innovation (NCTI) at the American Institutes for Research (AIR) and Pip Campbell and Suzanne Milbourne at Thomas Jefferson University, organizations whose OSEP-supported work is also at the forefront of technology in special education. In this article we provide a framework for further discussion of this significant issue by articulating the points of commonality and difference between AT and UDL.

Some individuals may see AT and UDL as identical, or conversely, antithetical. We believe that neither view is accurate but instead that AT and UDL, while different, are completely complementary—much like two sides of the same coin. We believe that advances in one approach prompt advances in the other and that this reciprocity will evolve in ways that will maximize their mutual benefits, making it essential that both approaches are pursued vigorously and distinctively. Through a better understanding and melding of AT and UDL, we believe that the lives of individuals with disabilities will ultimately be improved.

Two Roles for Technology: Assistive Technology and Universal Design for Learning

When most people imagine the role of technology for students with disabilities they think of AT. Relatively low-tech AT (like canes, wheelchairs, and eyeglasses) have been in place for a century, but the high-tech AT that has emerged

over the last two decades has made a particularly dramatic impact on education, and has also captured the imagination of the public (Behrmann & Schaff, 2001; Edyburn, 2002). These newer technologies include diverse items such as electronic mobility switches and alternative keyboards for individuals with physical disabilities, computer-screen enlargers and text-to-speech readers for individuals with visual disabilities, electronic sign-language dictionaries and signing avatars for individuals with hearing disabilities, and calculators and spellcheckers for individuals with learning disabilities. The enormous power of such computer-based technologies to assist individuals with disabilities in overcoming barriers to educational access, participation, and progress is evident in the research base (Crealock & Sitko, 1990; Hebert & Murdock, 1994; MacArthur & Haynes, 1995; MacArthur, Haynes, Malouf, Harris, & Owings, 1990; Raskind & Higgins, 1999; van Daal & Reitsma, 1993; von Tetzchner, Rogne, & Lilleeng, 1997; Xin & Rieth, 2001).

In contrast to AT, universal design, although well established in architecture and other domains, is relatively new to education. One indication of this newness is the lack of clarity about what constitutes universal design in education, and a lack of differentiation from other approaches that address individual differences and disabilities. For example, there is frequent confusion about the relation between universal design in education and AT, in large part because both approaches depend significantly on modern technology (Bowser & Reed, 2000; Hitchcock & Stahl, 2003). Universal design (and particularly the branch that focuses on education, UDL) has goals similar to those of AT, including the overarching goal of increasing the access, participation, and progress of students with disabilities in our schools. However, the approaches differ in important ways.

The universal design approach is to create products and/or environments that are designed, from the outset, to accommodate individuals with a wider range of abilities and disabilities than can be accommodated by traditional applications. Rather than retrofitting ramps to existing buildings, the universal design movement in architecture educated architects in how to design buildings that are inherently accessible (Story, Mueller, & Mace, 1998). Such buildings tend to be more accommodating and flexible for all users.

In a related fashion, UDL seeks to educate curriculum developers, teachers, and administrators in how to design curricula and learning environments that from the outset make learning accessible to the widest range of students (Rose & Meyer, 2002). The focus of UDL is the learning environment rather than any particular student. Its purpose is to identify potential barriers to learning in a curriculum or classroom and to reduce such barriers through better initial designs, designs with the inherent flexibility to enable the curriculum itself to adjust to individual learners (Miiller & Tschantz, 2003; Rose & Meyer, 2002).

Thus, although both AT and UDL rely on modern technology to improve education for students with disabilities, the technology tools used have a different site and mechanism of action. In AT, modern technology is employed at the level of the individual student to help him or her overcome barriers in the curriculum and living environments. With UDL, modern technology targets the curriculum itself; that is, technology is used to create curriculum and environments that, by design, lack traditional barriers to learning.

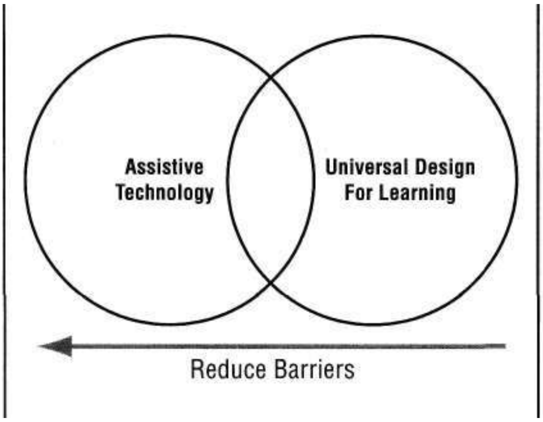
How Sharp Are the Distinctions Between Assistive Technology and Universal Design for Learning?

UDL and AT can be thought of as two approaches existing on a continuum. At the ends of this continuum, the two approaches are easily distinguishable. Toward the middle of the continuum, such easy distinctions are muddied, and there are greater points of interaction and commonality (Figure 1). Here we emphasize the interactions, because any comprehensive solution is likely to require attention to AT, UDL, and their effective integration. However, some crucial distinctions must also be understood.

Assistive Technology

Assistive technology is technology that increases, improves, or maintains the functional capabilities of students with disabilities.

Figure 1. The relationship between assistive technology and universal design for learning.



Usually it is specifically designed to assist individuals with disabilities in overcoming barriers in their environment and in increasing their opportunities for independence. Because the intended consumers are usually individuals, specifically individuals with disabilities, AT can be carefully engineered, fitted, and adapted to the specific strengths and weaknesses of each person. In that regard AT is unique, personal (travels with the individual), customized, and dedicated.

Universal Design

Universal design is a process for designing general (i.e., used by everyone) products or structures in such a way as to reduce barriers for any individual (either with or without disabilities) and to increase opportunities for the widest possible range of users. Because the intended consumers are groups of individuals (i.e., a whole community), universal designs are engineered for flexibility, designed to anticipate the need for alternatives, options, and adaptations. In that regard, universal designs are often malleable and variable rather than dedicated. They are not unique or personal, but universal and inclusive, accommodating diversity.

Universal Design for Learning

The term UDL emphasizes the special purpose of learning environments—they are not created to provide information or shelter but to support and foster the changes in knowledge and skills that we call learning. While providing accessible spaces and materials is often essential to learning, it is not sufficient. Success requires that the components of pedagogy—the techniques, methods, scaffolds, and processes that are embedded in classrooms and curricula—are also accessible, and that the measure of their success is learning. The UDL framework is based in the neuroscience of learning, and its principles emphasize three key aspects of pedagogy: the means of representing information, the means for the expression of knowledge, and the means of engagement in learning (Rose & Meyer, 2002).

The Importance of Interaction and Integration of AT and Universal Design

In practice, universal design and AT often work in concert to achieve optimal and practical results (Hitchcock & Stahl, 2003). The following examples illustrate the value of integrating universal design and AT in architecture and the classroom, respectively.

Integration of Assistive Technology and Universal Design in Architecture

Consider the problem of mobility for the person with a physical disability. On the one hand, mobility can be viewed as primarily an individual problem—individual physical limitations create a unique, personal need for adaptation or enhancement. Such a view underscores the need for assistive solutions, solutions that are designed to help the individual to overcome his limitations, usually through application of technology. Electronic wheelchairs, wheeled walkers, and the like are examples. The advantage of such solutions is that they can be precisely tailored to the specific needs of the individual—adaptive seating for support, individual switch placement for control, and so forth.

On the other hand, mobility can also be viewed as an environmental problem—limitations in the design of the environment create physical barriers to mobility. A building that offers only stairs for moving between floors or rooms creates barriers for many individuals, including those who are using wheelchairs or wheeled walkers for mobility. Such a view underscores the need for a properly designed

environment—one that provides alternatives like ramps and elevators. The advantage of such solutions is that they are universal, that is, they benefit not only a specific individual with a mobility barrier, but also many individuals, including nondisabled people, who are using baby carriages, carts, strollers, or pulling their luggage on wheels.

In reality, both the individual view and the environmental view are essential. If we focus only on the design of AT, we will inherit an environment that is so poorly designed and barrier-ridden that mobility will be limited for many individuals, creating a need for AT that is prohibitively extensive and expensive. The next generation of wheelchairs, for example, will be able to surmount barriers like stairs—a great advance—but they will cost many times more than existing wheelchairs, will be too cumbersome for many environments, and still face barriers like spiral staircases, ladders, and so on.

On the other hand, if we focus on universal designs at the exclusion of AT, we will fail to consider the customized adaptations that many people need and will build environments that are too complex and expensive. Many next-generation buildings, for example, will include ubiquitous moving walkways, but these will not adapt sufficiently for all individuals and will be prohibitively expensive and cumbersome for many buildings. Assistive technologies make universal designs more effective.

The most powerful and cost-effective solutions are ones that integrate these two approaches, yielding universal designs that are aware of the requirements of AT (e.g., buildings whose ramps have corners and inclines that are accessible to power wheelchairs) and AT that are aware of the affordances of universally designed buildings (e.g., wheelchairs that incorporate infrared switches to activate universally designed door and elevator buttons). Such integrated designs are not only more economical and ecological, they reflect the fact that disabilities are defined by the interaction between the environment and the individual.

Integration of Assistive Technology and Universal Design for Learning in the Classroom

Consider the problem for a student with a reading disability of mastering a history concept. Most history curricula pose significant barriers to such a student, especially the predominance of text. Most of the content is presented in text, and most of the assessment requires writing. This problem, too, can be viewed and solved in two different ways.

Taking an AT perspective, the problem can be considered an individual problem—it is clearly the individual student's reading disability that interferes with his or her ability to master the history content and demonstrate knowledge. This view fosters solutions that address the individual's weaknesses—remedial reading classes, special tutoring, and AT, for example. Of these, AT is particularly valuable because it provides independent means for the student to overcome his or her limitations by, for example using a spellchecker or audio version of the history book.

A UDL perspective, on the other hand, sees the problem as an environmental problem— the history curriculum's overreliance on printed text raises barriers to engagement and mastery for many students. This view fosters solutions targeting limitations in the curriculum rather than limitations in the student. Imagine a multimedia curriculum that provides digital, universally designed media that offer diverse options for viewing and manipulating content and expressing knowledge. Within such a flexible curriculum fewer students face barriers; digital text can speak aloud to reduce decoding barriers for students with dyslexia; digital images or video pro vide an alternative representation that reduces barriers in comprehension for students with language-based disabilities while providing descriptions and captions for students who are blind or deaf; and keyboard alternatives may reduce barriers in navigation and control for students with physical disabilities. These UDL solutions have the advantage of enhancing learning for many different kinds of students (Rose & Meyer, 2002).

In reality, both kinds of solutions are needed (Hitchcock & Stahl, 2003). In an educational setting, the disadvantage of exclusively

using AT is that it is not integrated with the learning goals of a given lesson. If that is the case, AT may not be helpful, or may even interfere, from an educational standpoint. For example, a spellchecker would be a valuable AT for a student with learning disabilities in many situations, but in a lesson on spelling it would be counterproductive. The proper use of a spellchecker must be determined contextually, with an eye toward the goals of the lesson rather than merely the student's general access technologies (MacArthur, Graham, Haynes, & De La Paz, 1996).

At the same time, a purely UDL solution has the disadvantage that some built-in accommodations, particularly for students with low-incidence disabilities, are cumbersome, inefficient, or prohibitively expensive when included as an element of the basic curriculum. It is not necessary or advantageous to provide a screen reader or alternative keyboard with every piece of curriculum—students are better served by individual AT that has been adapted and fitted precisely to their own capacities and that can be used across many different pieces of curriculum without further adaptation or change of settings.

It is essential that universally designed curricula be aware of common assistive technologies and accommodate their features in the design process. For example, a UDL curriculum that is not aware of the requirements for keyboard equivalents in order to interface properly with single-switch access devices and alternative keyboards cannot provide universal access. Similarly, assistive technologies must be aware of the features built into universally designed curricula so that they are complementary and expansive rather than redundant. A text-to-speech technology that does not recognize common tagging features (like links or long descriptions) cannot provide adequate access to curricular materials.

In the past, there have been all too few examples of universally designed curricula, and even fewer examples of optimal linkages between such curricula and AT. We believe the future will bring many more. The next section provides a contemporary example of the kinds of progress that we anticipate.

The National Instructional Materials Accessibility Standard: An Example of the Current Linkage Between Universal Design for Learning and Assistive Technology

New developments in policy and practice are illuminating the educational landscape ahead and shaping the operational linkage between AT and UDL. One illustrative example is the recent inclusion of the National Instructional Materials Accessibility Standard (NIMAS) as part of the forthcoming Individuals with Disabilities Education Act (IDEA) reauthorization (NCAC, 2003; Rose & Stahl, 2003).

We begin this section by examining the policy supporting this new legislation, and the technological efficiencies it is designed to implement. We then discuss how the increased, timely availability of alternate accessible versions of textbooks, a development supported by NIMAS, promises to have a significant impact on the educational use of AT and relates to the integration of AT and UDL. Lastly, we address how this state of affairs may impact the education of students with disabilities now and in the future.

NIMAS and Current Policy and Technology Constraints on the Availability of Accessible Textbooks

As noted earlier, traditional print-based textbooks so prevalent in most classrooms pose barriers for many students with disabilities. While many students who are educated in general education classrooms can take advantage of the resources available in textbooks, these same resources are largely unavailable to students who cannot see the words or images on a page, cannot hold a book or turn its pages, cannot decode the text, or cannot comprehend the syntax that supports comprehension. These students may all require different supports to extract meaning from information that is book bound, and many require the retrofitting of print-based materials.

Two problems constrain the availability of accessible textbooks. The first is a problem of policy, the second a problem of technology.

Policy

Copyright laws provide publishers with the protection under which they produce, format,

and distribute instructional materials. The content found in most textbooks used in K-12 classrooms is owned by individual or organizational rights holders who, not themselves publishers, grant fee-based permission to curriculum publishers to reproduce and use their materials. These permissions allow publishers to combine proprietary content with their own materials and distribute a product in an agreed-upon format or formats: print, audio book, CD-ROM, and so on. The original format for most K-12 textbooks is print, and traditionally it is this format for which publishers have secured and purchased copyright permissions. Unfortunately, when this is the case, legal agreements prevent publishers from providing more accessible versions of the materials.

However, students with disabilities and those supporting them have a legal means to acquire accessible versions of print textbooks by virtue of an existing copyright exemption. In September 1996, President Clinton authorized Section 121 of the United States Code, amending Chapter 1 of Title 17 and establishing a limitation on exclusive rights in copyrighted works. This legislative adjustment, commonly referred to as the Chafee Amendment (originally introduced by Senator John Chafee (R), Rhode Island) was specifically designed to create a legal conduit that would significantly enhance the flow of accessible, alternate format print works to the blind or other persons with disabilities. The Chafee Amendment copyright exemption was the culmination of efforts by disability advocates and the publishing community to create a mechanism that would obviate the need to seek, on a case-by-case basis, permission of the copyright holder every time a print work needed to be transformed into an alternate format for use by a person with a disability.

This exemption was designed as a relief valve for publishers and individuals with disabilities, allowing for the carefully monitored transformation of inaccessible materials into specialized formats for use by qualifying students (Perl, 2003).

Unfortunately, under current copyright law, only students with qualifying print disabilities may be provided with accessible braille, audio, or digital text versions of print materials without directly seeking permission from (and giving compensation to) the copyright holder. If the most conservative interpretation of the Chafee Amendment guidelines is applied, less than 5% of the nearly 6 million students who receive IDEA services and support would qualify to receive accessible instructional materials. In practice, there has been some flexibility in interpreting the Chafee Amendment guidelines, nevertheless the fact that the Chafee Amendment provides the only legal means of distributing accessible versions of proprietary materials to students with disabilities imposes a significant limitation when it becomes the basis for a compliance mandate in such expansive legislation as the IDEA.

The language in the current IDEA reauthorization includes a proposed modification to the copyright exemption that would allow publishers to provide digital files to authorized third parties specifically for the creation of accessible versions of textbooks for students with qualifying disabilities. This provision would include curriculum publishers within the Chafee exemption. While this modification would not expand access to these materials to a broader range of students than is presently identified under existing copyright law, it would significantly facilitate the flow of textbook files from producers to converters to users.

The significance of the inclusion of NIMAS in the IDEA as a mandate for both states and publishers cannot be overstated. It reflects widespread agreement among educators, disability advocates, and publishers, and it creates a precedent-setting national agenda by recognizing that instructional materials themselves, rather than the students using them, are in need of improvement. However, the fact that the right to accessible versions of print materials is extended to only a subset of IDEA-eligible students necessitates a more comprehensive alternative approach.

Technology

Beyond its application to IDEA-eligible students, the Chafee exemption created a new avenue for compliance with other federal mandates, including Section 504 of the Rehabilitation Act and the Americans with Disabilities Act. Since passage of the Chafee Amendment

in 1996, special educators, disability service providers, advocacy organizations and new not-for-profits created specifically to take advantage of the copyright exemption began to actively transform print materials into accessible alternate versions. As these localized operations became more sophisticated and learned to exploit the potential of desktop computer technologies, textbooks became the content most often transformed. As a result, it is now common to find alternate format materials produced in schools and districts, postsecondary institutions, and regional education service centers nationwide. Not surprisingly, as more educational institutions have become equipped to create alternate format materials, students, their families and their advocates have increased their awareness of, and, subsequently, their requests for this content.

A variety of stakeholders—educators, national advocacy organizations, curriculum publishers, and others—have realized that the copyright exemption, originally designed to address individual instances of print inaccessibility, is increasingly being relied upon as the cornerstone for large-scale content transformation. This creates a problem because much like the architectural retrofitting referenced earlier, large-scale content transformation can be costly and time consuming and often results in an academic experience that is not equal to that provided to nondisabled students. Because the creation of these alternate editions begins with retrofitting and transforming an existing print version, each one represents a custom product. There is no economy of scale, no consistent quality control, no guarantee of efficient or timely delivery, and no guarantee of a consistent or harmonious interface with changing assistive technologies.

The National Instructional Materials Accessibility Standard: Integrating Policy and Technology

In the late 1980s, the Instructional Materials and Solutions Forum (convened by the American Foundation for the Blind) brought together approximately 40 national stakeholder organizations to address, among other things, the need for a scalable technological solution that would make the process of providing accessible, alternate versions more efficient, consistent, and timely. This initiative ultimately resulted in the creation of the National File Format Technical Panel in 2002 by the United States Department of Education, Office of Special Education Programs (Rose & Stahl, 2003). Charged with identifying the technical specifications for the NIMAS, the agreement reached by the technical panel in the fall of 2003 resulted in the identification of a technological format for source (publisher provided) files that will facilitate the efficient and consistent production of quality alternative formats. The inclusion of this recommendation in the reauthorization of IDEA reinforces the technical consensus with a national mandate for adoption (NCAC, 2003; Rose & Stahl, 2003).

The National File Format Technical Panel recommended that the NIMAS version 1.0 be an application of an XML-based (extensible Markup Language) standard. The National File Format Technical Panel recommended the DTBook element set, a component of the ANSI/NISO Z39.86. This recommendation aligned the NIMAS with the work being done concurrently by the DAISY consortium (www.daisy.org), the Open eBook Forum (www.openbook.org), and the IMS Global Learning Consortium (www.imsproject.org), thus ensuring cross-industry standards conformance.

The curriculum publishing community agreed to make available digital files containing all of the elements of the print textbooks (a combination of XML and PDF files), and further agreed to identify the XML components according to the NIMAS 1.0 standard. As a result of this consensus, third-party conversion organizations (Recording for the Blind and Dyslexic, American Printing House for the Blind, National Braille Press, etc.) and school districts will receive consistent, valid, and well-formatted digital source files from which to create accessible and student-ready versions. This will cut the conversion time—and therefore the distribution time—significantly. The promise of the NIMAS standard is that alternative versions will be made available to students at the same time that print versions are made available to their nondisabled classmates.

While this agreement will significantly streamline the conversion process by eliminating existing incongruities in publisher files, its true impact will likely be as a precedent-setting designation of the critical importance of separating content from its presentation. XML-based files remain malleable, their baseline component labeling (tags) can be extended to encompass a wide range of presentation needs, and content stored in this format can ultimately be transformed not only into accessible alternate versions, but into new, universally designed, enhanced learning editions as well.

The NIMAS standard is both a policy advance (an advance that ensures equitable access to educational materials for all students) and a technology advance (an advance in the publishing workflow that will lead to more efficient distribution for publishers and consumers alike). While NIMAS is not yet broadly based enough to be called a true universal design, it is clearly the foundation for future universal designs that will be based on it.

Current Integration of UDL and AT: Accessible Curriculum Content Increases the Efficacy of Assistive Technology

The increased availability of flexible and inherently accessible core curriculum materials under NIMAS will probably lead to an increased awareness of AT and a broadening of its use. The reason is that accessible information is not necessarily optimized for every potential user and, therefore, may prompt the use of AT. Consider, for example, familiar technological solutions for everyday tasks: word processing for writing and revision, spellchecking for editing, email for communication, financial software to reconcile our bank balances. Each requires the interplay between an application program (word processor, email or spreadsheet software) and the files that contain the information being rendered (word processing document, email message, or financial worksheet). These software applications may each be customized to fit the individual needs of a user, and AT is simply the magnification of that customization to accommodate needs that are not inherently addressed by the application itself.

To take another example, a Web page can be built to ensure the highest degree of accessibility according to the World Wide Web Consortium's Web Access Initiative Standards (www.w3.org/wai). But the capabilities of the browser—Internet Explorer, Netscape, Mozilla, Opera, Safari or others—supply the transformational energy needed to realize this accessibility. Assistive technology acts on accessible instructional materials in an identical fashion, and, much as there is a direct correlation between the capabilities and use of browsers and the availability and functions of Web pages, a similar relationship exists between AT and the materials it acts upon.

What will be the effect of NIMAS, a foundation for universal design, on AT? The availability of a universal file format will optimize AT in a number of ways, including a) all publishers will be producing a common format for access, greatly reducing the complexity of design for interfacing AT, b) every state and district will optimally accept and use materials in a common format, greatly reducing the complexity of training and support for the personnel who will administer and use AT, and c) every student who needs them will get high-quality digital accessible materials in a timely fashion, rendering their AT more effective for classroom learning with their peers. Complementarily, the availability of high-quality AT in the classroom will render these new materials immediately useful for students and their teachers, and will allow teachers, special educators, and AT professionals to concentrate on learning rather than production of accessible materials. While either universally designed materials or AT in isolation can be helpful, it is at the intersection of the two that information access, and, ultimately learning, becomes most individualized and appropriate.

The intrinsic flexibility of digital alternate format versions of textbooks supports transformations not previously possible. For example, accessible alternate versions of textbooks can be transformed into braille files ready to be sent to an embosser for the creation of printed braille. Alternatively, digital textbook files can be formatted for a refreshable braille display, or for display on a computer screen with instantaneous onscreen braille to text and

text to braille conversion capabilities. This application allows teachers of the visually impaired, the majority of whom are sighted, to quickly and efficiently locate a paragraph, sentence, phrase, or even single word reference in a document—something that is very difficult to do with print braille. Similarly, subsections of a document can be translated to braille onscreen and either sent to a refreshable display print or an embosser, or translated into synthetic speech and saved as a portable audio (MP3) format. The alternate format (in this example, digital) provides the flexibility and the inherent transformative potential; the AT, refreshable braille display, synthetic speech, MP3 player, and so on allow the user (or those teaching them) to customize the experience for optimal benefit.

The schools, districts, and even states, that have begun to incorporate flexible digital versions of textbooks into their educational practice have increased their understanding of the importance and potential of AT devices and software. Because the emphasis on alternate format materials is on core curriculum resources, this awareness (and growing expertise) is extending well beyond special education and into general education classrooms. As a result, it is not as unusual as it once was to encounter a workshop on supported reading software during an institute for language arts teachers, and many schools are equipped with portable smart keyboards for word processing and text downloading; even MP3 players are no longer anomalies in the classroom—and they are not being solely used to store music.

The Future of Accessibility: Moving from Some Students to All Students

Existing copyright constraints limit the distribution of accessible alternate format materials, and thus fail to address the needs of alment of the NIMAS and its inclusion in the IDEA reauthorization does create the foundation for that solution. The scope of current local efforts to use technology to create accessible alternative versions of core textbooks has highlighted the need while simultaneously exposing the inaccuracies and inefficiencies inherent in an uncoordinated approach. It has also illuminated the weaknesses in the present system, establishing the impetus necessary to promote widespread change.

The most effective approach to providing accessible versions of print textbooks entails the creation of a free market distribution model. In this model publishers would create alternative and accessible versions of print textbooks for direct distribution to states, districts, schools, and students at the same time that the print versions are made available. In this model, accessible (likely digital) versions could serve a broad range of students' needs, well beyond the needs identified in the narrow exemption from copyright laws granted by Chafee. The free market approach could eliminate the delay in the development and distribution of accessible digital versions that currently exists. However, in order for a free market system to become established, a number of conditions must be met.

First, education consumers (states, districts, schools) must demonstrate a willingness to pay for the value represented in the publishers' production and delivery of fully accessible instructional materials. If the growing array of state textbook adoption legislation, that is, legislation mandating the provision of accessible versions that go beyond requiring digital text files to the inclusion of graphical elements and easy-to-use navigation, is an indicator, the demand is beginning to be established.

Second, publishers must be able to reclaim the rights that have been exempted under the Chafee Amendment in order to facilitate production investments, including the acquisition of all rights required for reproduction and distribution of materials in digital formats. While nontrivial, obtaining these rights is made much more enticing if the intellectual property holders and the publishers perceive that adequate compensation is viable.

Third, the workflow that produces print textbooks has to be adjusted to accommodate the creation of digital versions, not as a deflection of core product development and manufacturing efforts but as a naturally occurring variation in the product cycle. Many of the large curriculum publishing companies have begun to move in this direction—some as a direct result of the NIMAS consensus—by

establishing a digital workflow that can result in a number of published products, print textbooks and digital versions among them.

Fourth, third party conversion entities must prepare to meet an increased demand for their expertise. As commercial publishers move to establish a capacity to produce accessible digital versions for sale on the open market, organizations and companies that now perform the final step in the alternative format conversion, creating braille, digital audio or otherwise accessible editions, will find an increased demand for their skills as subcontractors or co-developers with curriculum materials producers.

None of these four conditions is felt to be unattainable, and the benefits to intellectual property holders, content developers, content conversion experts, and students with disabilities is readily apparent. Accessible digital versions would be provided to students with disabilities (who need them) and students without disabilities (who might prefer them). Intellectual property holders and content developers would be assured of adequate compensation and digital rights management. Content conversion experts would see their expertise in the development of alternative versions of instructional materials expand beyond the limited market in which they now exist into the broader educational enterprise. The NIMAS establishes an extensible foundation for moving this vision forward. This vision is moving toward a true universal design for learning.

Beyond Access —Towards the Learning Enterprise

While the stated purpose of determining the NIMAS specification was to facilitate the timely provision of accessible materials to students with disabilities, it is important to keep in mind that it is the nation's educational system within which these alternative versions will be provided. With that emphasis, the extent to which alternate, accessible versions of textbooks created from NIMAS-compliant source files enhance student achievement is a significant and very relevant question.

The answer to that question will require more research, research on outcomes (Edyburn, 2003). To date, flexible and accessible digital versions of core curriculum print textbooks have simply not been sufficiently available to measure their impact within the context of large-scale academic achievement. What is known, however, is that students with a wide range of disabling conditions—those who currently qualify as persons with print disabilities and those who do not—can benefit from universally-designed instructional solutions (Rose & Meyer, 2002).

A recent extensive summary of research in this area has been prepared by NCAC at www.cast.org/ncac (Strangman, Hall, & Meyer, 2003). Among many studies in this area are the following:

- Students with language-related disabilities showed positive effects for word recognition, comprehension, and fluency when using digital texts with synthetic, syllable- or letter name-level synthetic speech transformations (Elbro, Rasmussen, & Spelling, 1996).

- Students with attentional, organizational and learning disabilities have shown increased academic gain when exposed to technology-supported concept mapping strategies. (Anderson-Inman, Knox-Quinn, & Horney, 1996; Herl, O'Neil, Chung, & Schacter, 1999).

- Students who are deaf or hard of hearing show consistent academic gains when provided with the sequential text highlighting and supportive captions available with digital instructional materials (Andrews, & Jordan, 1997; Mclnerney, Riley, & Osher, 1999).

- Students with low cognitive abilities demonstrate increased functional skills when exposed to flexible technologies that maximize their strengths while helping to compensate for their weaknesses (Carroll, 1993; Wehmeyer, Smith, Palmer, Davies, & Stock, 2003).

The true promise of NIMAS is that it provides a flexible but sturdy foundation for curricula that embody UDL and capitalize on ATs to make that learning accessible to everyone. Realization of the promise of NIMAS will be apparent as a cultural shift for students with disabilities: the shift from a focus on access to a

focus on learning. That critical shift will depend upon the continued evolution of an optimal interplay between UDL and AT.

The Future of Assistive Technology and Universal Design for Learning

We expect a continuing dialogue along the continuum of Universal Design for Learning and assistive technologies. As UDL matures, it will advance by incorporating many features now provided only by assistive technologies, in the same way that text-to-speech, spellchecking, and calculators can be routinely built into office word processing or that captioning is built into every television. As assistive technology matures, it will advance by assuming increasing connectivity with universal designs, taking advantage of the common structures (e.g., XML semantic tagging in a universally designed Web site) to provide highly individualized solutions that are not only sensory- and motor- but also cognitive- and linguistic-oriented. During this period of AT and UDL maturation and advancement, we must make every effort to ensure that these two fields develop symbiotically. When UDL and AT are designed to co-exist, learning for all individuals is enhanced.

In a world where we are very aware that understanding human behavior requires knowledge of the complex interaction between both cultural and individual development, we should not be surprised to find that fostering human learning will require access solutions that are optimal interactions between what is universal and what is individual.

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